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An Evaluation of Egg Carton Materials and Designs

Contents

An Evaluation of Egg Carton Materials and Designs

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Preface and Acknowledgment

This report is part of a continuing research program of the U.S. Department of Agriculture designed to find more efficient and less costly methods of packaging, handling, and transporting agricultural products from producer to consumer.

The egg grading on which this report is based was performed under contract by State licensed inspectors of the States in which the field work was done.

The author extends appreciation to the State Departments of Agriculture of Florida, Illinois, Minnesota, New York, and Texas for providing the inspectors who performed the egg grading and helped coordinate the study; and to Hedy Ross, Market Research and Development Division, AMS, USDA, for conducting the statistical analysis of the test data and providing a technical review of the report.

Appreciation is also extended to the following, who contributed their time and facilities: Lloyd Jones, Kuder Eggs, Waverly, Fla.; Zephyr Egg Co., Zephyrhills, Fla.; Albertsons, Lauderhills, Fla.; Mel Sheffner, Southern Farms, Germantown, Ill.; Produce Wagon, Springfield, Ill.; Crown Produce Co., St. Louis, Mo.; Crystal Farms, Gaylord, Minn.; Jack Frost Food Co., Rice, Minn.; Morterud's Eggs, Duluth, Minn.; Golden Valley Super Valu, Minneapolis, Minn.; Penny's Supermarket, Minneapolis, Minn.; Denfeld's Supervalu, Duluth, Minn.; Piggly Wiggly, Duluth, Minn.; Kenneth Smith, Beacon Farms, Middlesex, N.Y.; Thousand Island Farms, Redwood, N.Y.; Ginerrich's Egg Factory, Castorland, N.Y.; Ed's Specialty, Interlaken, N.Y.; Palomaki farms, Van Etton, N.Y.; Regional Poultry and Egg Market, Rochester, N.Y.; Cal Maine, Lubbock, Tex.; Pilgrim Industries (Sunco Poultry and Egg Division), El Paso, Tex.; Furr's Supermarket, Midland, Tex.; J.R. Beadel, Brownwood, Tex.; and West Foods, Inc., Hobbs, N. M.

Special appreciation is extended to Joseph W. Bow and Robert W. Foster of the Single Service Institute, Inc., Washington, D.C., and to the egg carton manufacturers who cooperated in this study.

Summary

The study evaluated the protective capability of ten commonly used 12-egg cartons at both the originating packing plant and at shipping destination. Cartons consisted of six plastic foam (F) and four molded pulp (P) designs. Two commonly used types of master containers were used for packing and shipping the egg cartons: 15-dozen baskets (wire or plastic) and 30-dozen fiberboard cases.

Research took place in 7 States during each of the seasons of the year, consisted of 42 completed truck shipments, and lasted over a period of 2-½ years. Egg grading was done by State-licensed inspectors, and was performed in 8 large packing plants, 9 central distribution warehouses, and 11 retail supermarkets.

After information on eggshell damage was collected, data were subjected to analysis of variance and Duncan's multiple range test to separate means. Statistical significance was at the 5-percent level of probability.

A greater range of damage was found among foam cartons than among pulp cartons; the differences in damage rates between the two groups were generally minimal.

There was significant difference in total eggshell damage rates between material groups only when the effect of master containers was considered. However, the pattern of damage indicated that eggs in the foam carton group had more damage at the plant, and eggs in the pulp carton group had more damage at destination. Comparing all 10 carton designs when the effect of individual master containers was not considered, the total rate of damage to eggshells in test cartons F2 and F1 at 5.40 and 5.68 percent, respectively, was significantly less than damage to eggshells in test cartons F4, F6, and P3 at 7.46, 7.31, and 7.15 percent, respectively. There was no significant difference in rates of eggshell damage among cartons F2, F1, P1, P4, P2, and F3.

Differences in eggshell damage rates between the two material groups were quite apparent when cartons were packed in 15-dozen baskets. Eggs packed in foam

cartons had significantly more total damage than eggs packed in pulp cartons, most of whose damage occured at the packing plant. When comparing all 10 carton designs within 15-dozen baskets, the total damage rate to eggshells in test carton F2 with 6.96 percent damage was significantly less than damage to eggshells in cartons F3, F6, F5, and P3 with 11.10, 10.75, 9.19, and 9.17 percent, respectively. There was no significant difference in damage rates for eggshells in cartons F2, P4, P1, P2, F4, and F1.

When eggs were packed in 30-dozen fiberboard cases, there was no significant difference in total eggshell damage rates between eggs packed in foam cartons and those packed in pulp ones. When comparing all ten carton designs within 30-dozen cases, the total damage to eggshells in test carton F1 with 4.18 percent was significantly less than damage to eggshells in test cartons F4, P3, F5, and P4 with 7.12, 6.04, 5.94, and 5.79 percent, respectively. There was no significant difference among cartons F1, F3, P1, P2, and F6.

Throughout this study, cartons F1, F2, P1, and P2 consistently performed at or above average, and the rate of damage to eggshells in them did not differ significantly. However, this does not preclude other cartons tested, since most performed adequately. Because of the range of eggshell damage within the material groups, it is recommended that choice of cartons be made on their individual merits based on type of master container being used as reflected in this research.

This report should not be the sole determining factor in choice of cartons or master containers. Marketing strategies and handling systems costs need to be examined and the optimum mix obtained.

Introduction

Background

Shell egg packaging is a critical factor in maintaining eggshell quality from the packing line to the retail store. Mellor and Gardner[1] have indicated that under "normal" conditions, packaging, material and design may be inconsequential to damage if all other variables, such as handling equipment, employee competence, truck suspension, road conditions, retail store management, and storage facilities, are adequate. However, because the above variables are not always controllable, "normal" handling, shipping, and receiving of shell eggs is not always possible.

Most comprehensive shell egg-packaging studies in the past have been limited to laboratory research.[2] Small-scale egg carton studies have been conducted in the field, but because of the often narrow tolerances between damage rates of different cartons and the limited number of trials to which these cartons were subjected, it has been difficult to come to any decisive conclusions about the protective capability of the test cartons.

Purpose of Study

The purpose of this study was to evaluate the protective capability of 10 commonly used 12-egg cartons at both the originating packing plant and at shipping destination, by use of two types of master containers.

Scope of Study

The study took place in seven States: Florida, Illinois, Minnesota, Missouri, New Mexico, New York, and Texas. Egg grading was performed in each of these States from November 1978 to May 1981. Eight large packing plants, 9 central distribution warehouses, and 11 retail supermarkets participated in the research.

Ten 12-egg cartons were tested (Figs. 1 and 2). These cartons consisted of six plastic foam and four molded pulp designs. Three of the six foam cartons and all of the pulp cartons were posted, and all 10 cartons had front closures.

[1]Interior Quality and Breakage of Shell Eggs," Poultry Science: Vol. XLIX, No. 3. 1970.

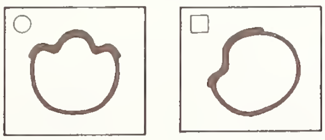
[2]Nethercote, et al. "Egg Carton Tests," Poultry Science 53:311-325, 1974.

There were various egg cell configurations among the cartons. The tops of the cell dividers within each carton were either level (parallel to the carton base), scalloped ("U" or reversed "U" shaped), or a combination of the two.

The following is a brief description of each test carton. "Vertical" refers to the short and "horizontal" refers to the long dimension.

Plastic foam (F series)

F1 — Flat top with three level vertical and two reversed "U"○ horizontal dividers towards the center of the carton. The outer cells have two partial reversed "U"□ vertical and two level horizontal dividers.



F2 — Similar to F-1 except for a short vertical top post.

F3 — Flat top with "U" certical and horizontal dividers.

F4 — Short vertical top post, six reversed "U" horizontal cell dividers, and five level vertical dividers with the two ends broken by central "U" scallops.

F5 — Two horizontal top posts with "U" vertical and horizontal dividers.

F6 — Flat top with reverse "U" vertical and horizontal dividers.

Molded pulp (P series) - the cell dividers of the following cartons are "U" shaped vertically and horizontally.

P1 — Open top design with five top and five bottom posts.

P2 — vertical top post in the center and four bottom posts extending to the carton top.

P3 — Wide horizontal top post and five bottom posts.

P4 — Flat top with five bottom posts extending to the carton top.

Two commonly used types of master contianers were used for packing and shipping egg cartons: 15-dozen baskets (wire or plastic) and 30-dozen fiberboard cases (fig. 3). It was not within the scope of this research to evaluate the master containers except as variables in transporting eggs. However, another publication[3] may be a useful guide in determining the differences in the protective capabilities of 15-dozen baskets and 30-dozen cases, depending on stacking patterns of cartons within them regardless of carton type.

On several occasions, one or more master containers of eggs were observed receiving unusually harsh or uneven treatment. The damage results from these containers were discarded from the analysis.

The data for this research were based on 42 truck shipments. The total number of egg inspections (candlings) within the 42 shipments were:

Location	**Number of eggs**
Packing plant	83,100
Destination	[4]76,900
Total	160,000

The eggs in this survey were grade A or AA large and came from birds of all breeds and conditions. Eggs for each shipment, however, came from the same flock of birds. Assuming similar handling conditions, this ensured that all chance of damage was normally distributed before packaging.

The study was designed to include egg shipments representing three age categories of laying hens for each season of the year: laying hens under 40 weeks old, 40-60 weeks old, or over 60 weeks old.

[3]Lederer, Bruce E. Eggshell Damage From End of Packing Line to Supermarket. U.S. Dept. Agric., Agric. Resr. Serv., ARS-NE-93, 1978.

[4]Of the shell eggs shipped from the packing plant, 6,200 were not inspected at destination because the 62 master containers within which they were packed received unequal treatment in transit or upon receipt.

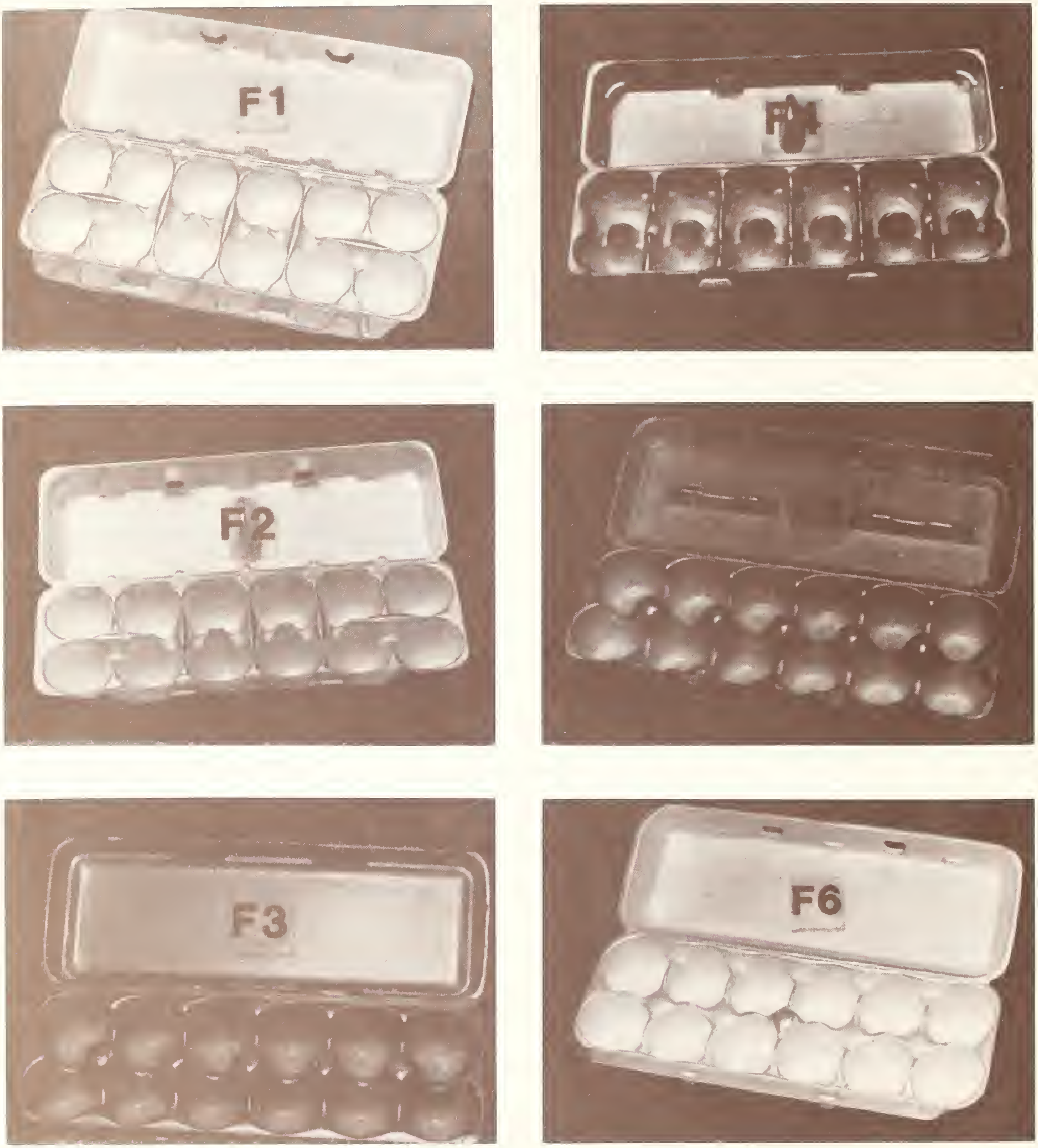


Figure 1.—Test egg cartons made of plastic foam.

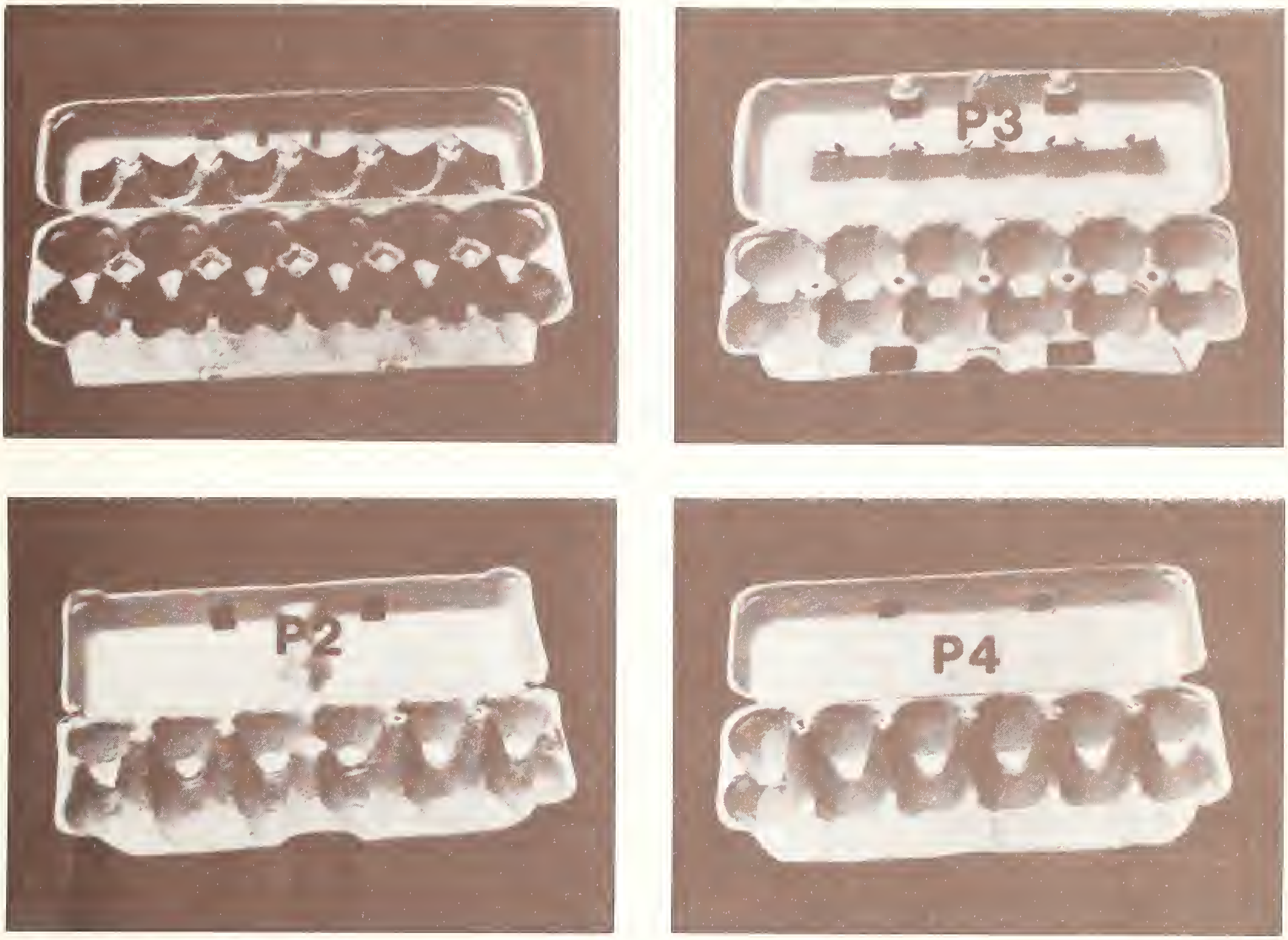


Figure 2.—Test egg cartons made of molded pulp.

Because of variables that were not controllable (diet and breed of laying hens, and handling procedures of packing plants within and among States during the same or different seasons), an analysis of damage by age of laying hen and season of year was not reflected in this report. However, the broad exposure of the test cartons to these varying conditions indicates the damage that could be expected during normal year-round operations.

It should be noted that manufacturers of egg cartons make occasional changes and modifications to the cartons, and although outward appearance of cartons may be similar, certain structural differences may occur. Thus, cartons reflected in this study are not necessarily identical to those now being produced.

Most information was obtained from onsite inspection by State licensed inspectors. Additional information was obtained from owners, managers, and employees of shell egg-packing plants, warehouses and supermarkets, Federal and State government officials, university personnel, carton manufacturers, and others involved with the handling of shell eggs.

Figure 3.—Two types of master containers: 15-dozen baskets—wire (left) and plastic (center)—and 30-dozen fiberboard case (right).

The term "damage" in this report refers to both checks and leakers. A *check* is an individual egg that has a broken shell or crack in the shell with its shell membrane intact. The range of check damage extends from a very fine hair-like crack (blind check) to plainly visible dented shells. A *leaker* is an individual egg that has a crack or break in the shell and shell membrane to the extent that the egg contents are exuding or free to exude through the shell.

To simplify this report, checks and leakers have been combined under the heading of "damage." Interior deterioration has not been considered.

Throughout this study, emphasis has been on relative eggshell damage rates among the cartons under various circumstances. Absolute damage rates to eggs packed in cartons in any one category have been discussed in reference to the relative damage to eggs among cartons within the category.

The term "destination" in the report refers to either warehouse or supermarket. If egg shipments normally were delivered to a warehouse before going on to a supermarket, then the warehouse would be the destination for purpose of the study. If truck shipments went directly from the packing plant to the supermarket, then the supermarket would be the destination.

Because of the significant variation among cartons in damage to eggs occurring at the packing plant, damage at the plant has been considered as part of the evaluation. The sum of plant plus destination damage is used to determine the protective capabilities of the 10 cartons, based upon the criteria established for this study.

Rates of damage in the text are arrayed in ascending order when discussing least amounts of damage, and descending order when discussing greatest amounts of damage. Where there is no significant difference among cartons, they are arrayed in ascending order.

Experimental Procedures

There were 20 master containers of eggs for each truck shipment.[5] For shipments where 15-dozen baskets were used as master containers, the egg cartons within the baskets were stacked in parallel fashion (fig. 4). For shipments using 30-dozen cases, the cartons were cross-stacked (fig. 5). This stacking arrangement of cartons within the respective master containers will result in the least damage.*

At both the packing plant and destination checkpoints, graders examined the test eggs for checks and leakers according to the standard U.S. Department of Agriculture random sampling procedures.[6]

Because of the large number of packing plants and destination points that were involved, handling methods varied considerably. The description here is considered typical for the majority of the facilities. It should be noted that, although handling methods differed from plant to plant and from destination to destination, each master container within each individual shipment was of the same type (either wire or plastic basket, or fiberboard case) and was handled the same as all other containers in the shipment.° This kept chances of damage to any one of them equal.

At the packing plant, cartons of eggs were packed in master containers at the end of the packing line (fig. 6), moved to the grading area, identified by pen or tag on the outside of the container, and then graded (fig. 7). Eggs with checks were identified with a penmark on the end of the damaged egg, recorded on the worksheet, then returned to their original position in the carton. Leakers were recorded, then were removed and replaced with sound shell eggs.

After grading, the master containers were placed on pallets and moved to the cooler. Each pallet, making up one shipment, had 20 master containers on it—2 each of the 10 types of the test cartons. After sitting for from eight hours to 4 days in the cooler, a pallet of eggs was transported to the loading dock and handstacked randomly at the rear of the transport vehicle. On

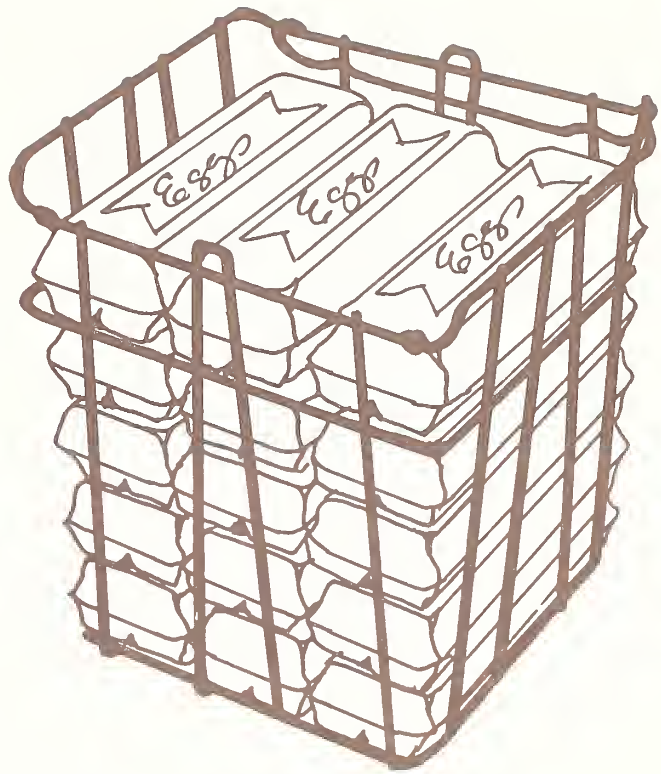


Figure 4.—Cartons in 15-dozen baskets are parallel stacked.

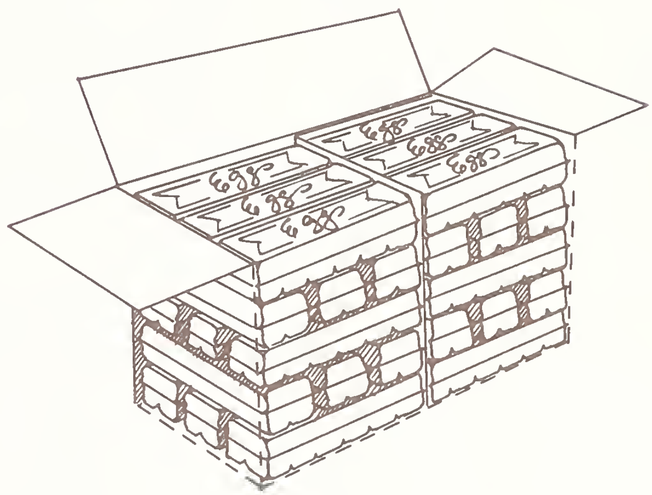


Figure 5.—Cartons in 30-dozen cases are cross stacked.

[5]Occasionally, one or two carton types were not available for particular shipments. On these occasions, there were less than 20 master containers per shipment.

[6]See appendix—Sampling Procedures.

*See footnote 3.

°See footnote 4.

Figure 6.—Packing master containers on the line.

several occasions, the test containers were placed on pallets instead of being stacked by hand, but this did not occur enough times to affect results.

Most shipments were delivered on straight body trucks for short hauls or tractor trailers for long hauls (fig. 8). The one-way distance between packing plant and destination (either warehouse or supermarket) ranged from 40 to 300 miles with an average one-way distance of 135 miles. Driver competence varied as did the suspension of the vehicle and road conditions. It is assumed that variations due to these transportation factors were normally distributed among the 42 shipments observed, These vehicles were all fully loaded.

At destination, the eggs were unloaded in their normal fashion either at street level or at dock height. Most shipments were unloaded by 2- or 4-wheeled handtrucks; the rest were unloaded by conveyor belt. The containers of eggs were then moved to the grading area and inspected for damage that might have occurred between point of first inspection at packing

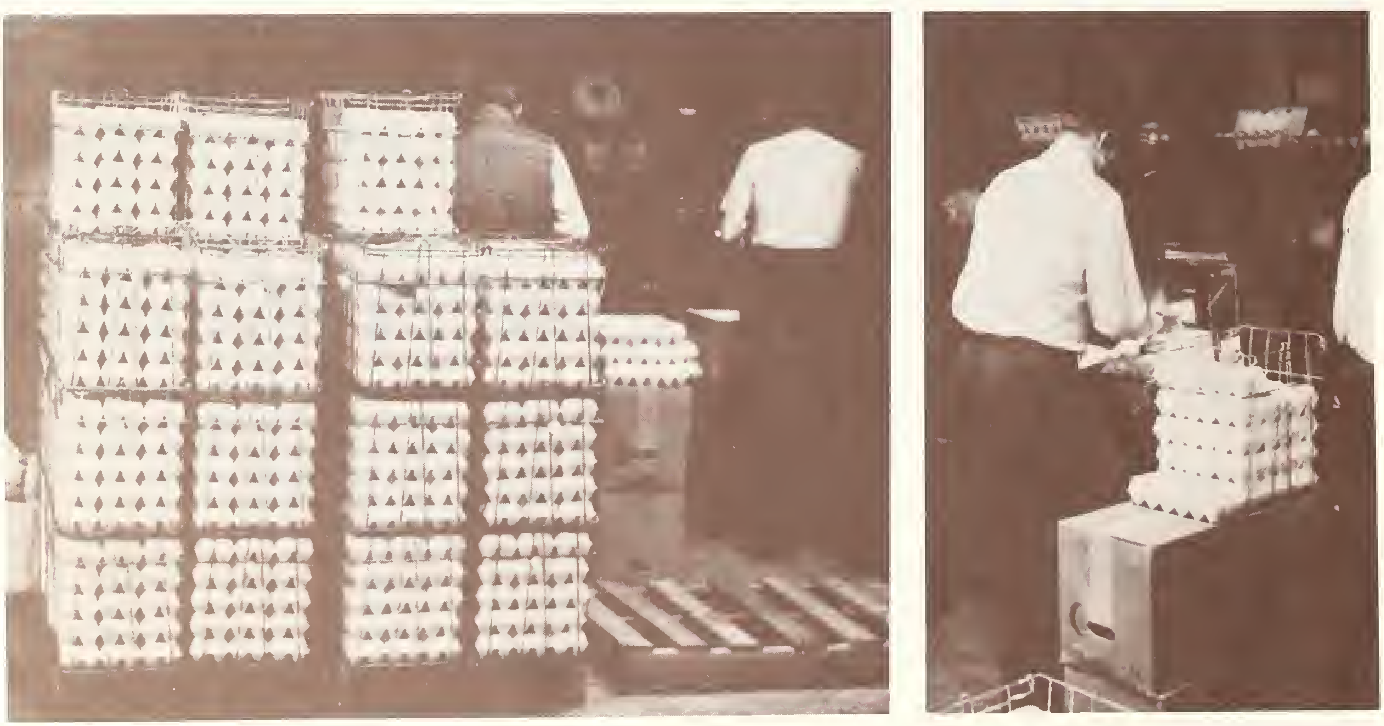


Figure 7.—Test eggs are moved to inspection are (left) and Graded (right).

plant and destination. Checks with a pen mark were not recorded on the worksheet because they had been already recorded at the packing plant. If checks from the plant became leakers at destination, the latter damage was not counted a second time.[7] All the newly damaged eggs were recorded on the worksheet and their cell locations within the carton noted.

After information of eggshell damage was collected, data were subjected to analysis of variance and Duncan's multiple range test to separate means. Statistical significance was at the 5-percent level of probability.

Figure 8—Two principal modes of shipment: straight body truck used for short hauls (above) and trailer used for long hauls (below).

[7]It is interesting to note, however, that 32 percent of the leakers found at destination had been observed to be checks at the plant. This supports earlier research (see footnote 3) indicating that 29 percent of the leakers found at destination had been observed to be checks at the plant.

Results

This section reflects the rate of damage occurring at the packing plant and destination checkpoints. Each observation[8] was discretely identified in order to track incidences of damage. Because 64 observations accidentally experienced unusual damage, they were deleted, resulting in more observations at the plant (831) than there were at destination (769), as shown in table 1. Also the destination grading included two observations that had not been examined at the plants. Thus there were 767 observations graded and tracked through both locations.

Tables 1 and 2 represent the average eggshell damage observed within all 10 test cartons and 2 master containers and gives a general profile of the overall rates and locations of damage along the marketing channel.

Tables 3 through 6 reflect the average damage rates of eggshells by material and design of test carton regardless of master container. Tables 7 through 10 reflect the average damage rates of eggshells by material and design of test carton when packed in 30-dozen fiberboard cases. Table 11 through 14 reflect the average damage rates of eggshells by material and design of test carton when packed in 15-dozen baskets.

Total Damage

Table 1 shows the average rate of eggshell damage regardless of carton or master container. The average rate of eggshell damage observed amounted to 4.75 percent at the plant and 1.93 percent additional damage at destination. The average rate of damage for those observations that were graded at both the plant and destination was 6.48 percent.

Table 1.—Rate of damage to eggshells regardless of carton or master container

Grading location	Observations	Damage rate
	Number	*Percent*
Plant	831	4.75
Destination	769	1.93
Both plant and destination[1]	767	6.48

[1]Numbers are not additive because a few observations were graded at each location that were not graded at both.

[8]One observation was comprised of 100 eggs within one master container.

Table 2 shows the location within cartons of damaged eggshells at destination (see fig. 9 for cell location). This is comprised of damage occurring after the initial grading at the packing plant. The highest damage rate occurred at the rear of the cartons and amounted to 57.0 percent of the destination damage, as contrasted with the 40.4 percent rate that occured at the front of the cartons.

Table 2.—Location of damaged eggshells within cartons at destination

Carton cell	Obser-vations	Damage rate	Percent of all destination damage
Front	*Number*	*Percent*	*Percent*
1	720	0.14	7.3
2	718	.15	7.8
3	719	.13	6.7
4	718	.14	7.3
5	719	.11	5.7
6	718	.11	5.7
All front cells	[1]718	.78	40.4
Rear			
7	719	.19	9.8
8	717	.18	9.3
9	718	.16	8.3
10	718	.17	8.8
11	718	.18	9.3
12	717	.22	11.4
All rear cells	[1]716	1.10	57.0
All destination damages	[2]769	[2]1.93	[2]100

[1]Only those observations for which a value was available for all components were used in the calculation of front or rear cell damage.

[2]The destination observation number was greater than the observation numbers of the front and rear of the carton samples. This occurred because in some test shipments, all the damage at destination was not identified by cell location. Therefore, damage percentage rates do not add up to 1.93, and percent of damage at destination does not add up to 100.

Damage Rate of Eggshells by Material and Design of Carton

Table 3 shows the average rate of damage to eggshells by carton material regardless of master container. There is a significantly lower rate of damage for pulp cartons at the plant and a lower rate of damage for foam cartons at destination. The difference between the total damage rates of eggshells in the two materials, however, is insignificant.

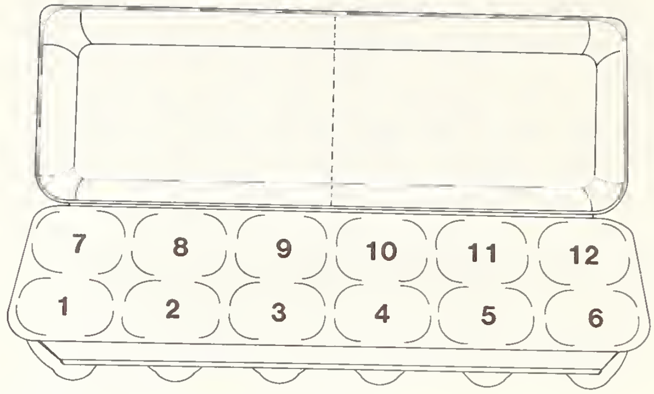


Figure 9—Location of damaged eggshells.

Table 4 shows descending damage rates of eggshells among foam carton designs regardless of master container. Although no significant difference among cartons occurred at the plant, there was a significant difference occurring at destination. The total damage to eggshells in test cartons F2 and F1 with 5.40 and 5.68 percent, respectively, was significantly less than that in cartons F4 and F6 with 7.46 and 7.31 percent, respectively. Damage rate in carton F3 was not significantly different from that in F1 and F2. Note: There was no significant difference in eggshell damage rates between posted (with posts) and unposted (flat top) designs among foam cartons.

Table 5 indicates no significant difference in damage rates to eggshells among pulp carton designs regardless of master container.

Table 3.—Average rate of damage to eggshells by carton material regardless of master container[1]

Material	Plant		Destination		Both plant and destination[2]	
	Number of obs.	*Percent damage*	*Number of obs.*	*Percent damage*	*Number of obs.*	*Percent damage*
Form	481	5.03	443	1.74	442	6.55
Pulp	350	4.35	326	2.19	325	6.40

[1]Numbers connected by the same bracket do not differ significantly at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Table 4.—Descending damage rates of eggshells in foam cartons regardless of master container[1]

Plant			Destination			Both plant and destination[2]		
Carton identification number	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*
F6	66	5.67	F6	60	2.15	F4	79	7.46
F4	85	5.58	F4	79	2.09	F6	59	7.31
F5	86	5.29	F3	67	1.75	F5	80	7.00
F3	73	4.95	F5	80	1.73	F3	67	6.63
F1	87	4.48	F2	78	1.50	F1	79	5.68
F2	84	4.37	F1	79	1.35	F2	78	5.40

[1]Numbers connected by the same bracket do not differ significantly at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Table 5.—Descending damage rates of eggshells in pulp cartons regardless of master containers[1]

Plant			Destination			Both plant and destination[2]		
Carton identification number	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*
P3	88	4.58	P3	82	2.52	P3	82	7.15
P4	87	4.44	P2	80	2.19	P2	79	6.39
P2	86	4.43	P1	83	2.08	P4	81	6.21
P1	89	3.98	P4	81	1.96	P1	83	5.84

[1]Numbers connected by the same bracket do not differ significantly at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Table 6 shows descending damage rates of eggshells among all carton designs regardless of master container. Looking at total damage among the 10 cartons, eggs in test cartons F2 and F1 with 5.40 and 5.68 percent damage, respectively, had significantly less damage than those in cartons F4, F6, and P3 with 7.46, 7.31, and 7.15 percent, respectively. There was no significant difference in damage to to eggs in cartons F2, F1, P1, P4, P2, and F3.

Damage Rate of Eggshells by Material and Design of Cartons When Packed in 30-dozen Cases

Table 7 shows the average rate of damage to eggshells by carton material when packed within 30-dozen fiberboard cases. There was no significant difference in the total damage rates between foam and pulp cartons.

Table 8 shows descending damage rates of eggshells-in pulp carton designs within 30-dozen fiberboard cases. Carton F1 with 4.18 percent had significantly less total damage than carton F4 and F5 with 7.12 and 5.94 percent, respectively. There was no significant difference in damage among cartons F1, F3, F2, and F6.

Table 6.—Descending damage rates of eggshells in all cartons regardless of master container[1]

Plant		Destination		Both plant and destination[2]	
Carton identification number	*Percent damage*	*Carton identification number*	*Percent damage*	*Carton identification number*	*Percent damage*
F6	5.67	P3	2.52	F4	7.46
F4	5.58	P2	2.19	F6	7.31
F5	5.29	F6	2.15	P3	7.15
F3	4.95	F4	2.09	F5	7.00
P3	4.58	P1	2.08	F3	6.63
F1	4.48	P4	1.96	P2	6.39
P4	4.44	F3	1.75	P4	6.21
P2	4.43	F5	1.73	P1	5.84
F2	4.37	F2	1.50	F1	5.68
P1	3.98	F1	1.35	F2	5.40

[1]Numbers connected by the same bracket do not differ significantly at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Table 7.—Average rate of damage to eggshells by carton material within 30-dozen fiberboard cases[1]

Material	Plant		Destination		Both plant and destination[2]	
	Number of obs.	*Percent damage*	*Number of obs.*	*Percent damage*	*Number of obs.*	*Percent damage*
Foam	308	3.68	295	1.53	294	5.34
Pulp	223	3.52	215	1.96	214	5.55

[1]Numbers connected by the same bracket do not differ significantly at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Table 8.—Descending damage rates of eggshells in foam cartons within 30-dozen fiberboard cases[1]

Plant			Destination			Both plant and destination[2]		
Carton identification number	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*
F4	53	4.66	F4	51	2.27	F4	51	7.12
F5	56	4.46	F6	40	1.83	F5	54	5.94
F6	42	3.52	F5	54	1.35	F6	39	5.54
F2	55	3.33	F3	46	1.35	F2	53	4.66
F3	48	3.13	F2	53	1.26	F3	46	4.59
F1	54	2.89	F1	51	1.20	F1	51	4.18

[1]Numbers connected by the same bracket do not differ significantly at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Table 9 shows descending damage rates of eggshells in pulp carton designs within 30-dozen fiberboard cases. There was no significant difference among total damage rates.

Table 10 shows descending damage rates of eggshells by all carton designs within 30-dozen fiberboard cases. The total damage of carton F1 with 4.18 percent was significantly less than cartons F4, P3, F5, and P4 with 7.12, 6.04, 5.94, and 5.79 percent, respectively. There was no significant difference in damage to eggs among cartons F1, F3, F2, P1, and F6.

Table 9.—Descending damage rates of eggshells in pulp cartons within 30-dozen fiberboard cases[1]

Plant			Destination			Both plant and destination[2]		
Carton identification number	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*
P4	58	4.14	P3	53	2.17	P3	53	6.04
P3	55	3.73	P2	51	2.14	P4	56	5.79
P2	53	3.19	P1	55	1.85	P2	50	5.50
P1	57	3.00	P4	56	1.71	P1	55	4.89

[1]Numbers connected by the same bracket do not differ significantly at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Table 10.—Descending damage rates of eggshells in all cartons within 30 - dozen fiberboard cases.

Plant		Destination		Both plant and destination[2]	
Carton identification number	*Percent damage*	*Carton identification number*	*Percent damage*	*Carton identification number*	*Percent damage*
F4	4.66	F4	2.28	F4	7.12
F5	4.46	P3	2.17	P3	6.04
P4	4.14	P2	2.14	F5	5.94
P3	3.73	P1	1.86	P4	5.79
F6	3.52	F6	1.83	F6	5.54
F2	3.34	P4	1.72	P2	5.50
P2	3.19	F3	1.35	P1	4.89
F3	3.13	F5	1.35	F2	4.66
P1	3.00	F2	1.26	F3	4.59
F1	2.89	F1	1.20	F1	4.18

[1]Numbers connected by the same bracket do not differ significantly at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Damage Rate of Eggshells by Material and Design of Cartons When Packed in 15-dozen Baskets

Table 11 shows the average rate of damage to egg shells by carton material within 15-dozen baskets. The total damage rate of eggs in pulp cartons at 8.03 percent was significantly less than that of eggs in foam cartons at 8.94 percent. Most of the difference occurred at the plant with eggs in foam cartons receiving an appreciably higher rate of checks than eggs in pulp cartons.

Table 12 shows descending damage rates of eggshells in foam carton designs within 15-dozen baskets. The total damage rate of eggs in carton F2 at 6.96 percent was significantly less than that of eggs in cartons F3, F6, and F5 at 11.10, 10.75, and 9.19 percent, respectively. There was no significant difference in damage to eggs among cartons F2, F4, and F1.

Table 13 shows descending damage rates of eggshells in pulp cartons within 15-dozen baskets. The total damage rate of carton P4 at 7.16 percent, was significantly less than carton P3 at 9.17 percent. There was no significant difference in damage to eggs in cartons P4, P1, and P2.

Table 14 shows descending damage rates of eggshells in all cartons within 15-dozen baskets. The total damage rate of eggs in carton F2 at 6.96 percent was significantly less than that of eggs in cartons F3, F6, F5, and P3 at 11.10, 10.75, 9.19, and 9.17 percent respectively. There was no significant difference in damage rates to eggs among cartons F2, P4, P1, P2, F4, and F1.

Table 11.—Average rate of damage to eggshells by carton material within 15-dozen baskets[1]

Material	Plant		Destination		Both plant and destination[2]	
	Number of obs.	*Percent damage*	*Number of obs.*	*Percent damage*	*Number of obs.*	*Percent damage*
Form	173	7.44	148	2.17	148	8.94
Pulp	127	5.82	111	2.63	111	8.03

[1]Individual brackets indicate significant difference between foam and pulp carton damage rates, at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Table 12.—Descending damage rates of eggshells in foam cartons within 15-dozen baskets[1]

Plant			Destination			Both plant and destination[2]		
Carton identification number	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*
F6	24	9.42	F6	20	2.80	F3	21	11.10
F3	25	8.44	F3	21	2.62	F6	20	10.75
F4	32	7.09	F5	26	2.50	F5	26	9.19
F1	33	7.09	F2	25	2.00	F1	28	8.43
F5	30	6.83	F4	28	1.75	F4	28	8.07
F2	[1]29	6.35	F1	28	1.64	F2	25	6.96

[1]Numbers connected by the same bracket do not differ significantly at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Table 13.—Descending damage rates of eggshells in pulp cartons within 15-dozen baskets[1]

Plant			Destination			Both plant and destination[2]		
Carton identification number	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*	*Carton identification number*	*Number*	*Percent*
P2	33	6.42	P3	29	3.17	P3	29	9.17
P3	33	6.00	P1	28	2.54	P2	29	7.93
P1	32	5.72	P4	25	2.52	P1	28	7.71
P4	29	5.03	P2	29	2.28	P4	25	7.16

[1]Numbers connected by the same bracket do not differ significantly at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Table 14.—Descending damage rates of eggshells in all cartons within 15-dozen baskets[1]

Plant		Destination		Both plant and destination[2]	
Carton identi-fication number	*Percent damage*	*Carton identi-fication number*	*Percent damage*	*Carton identi-fication number*	*Percent damage*
F6	9.42	P3	3.17	F3	11.10
F3	8.44	F6	2.80	F6	10.95
F4	7.09	F3	2.62	F5	9.19
F1	7.09	P1	2.54	P3	9.17
F5	6.83	P4	2.52	F1	8.43
P2	6.42	F5	2.50	F4	8.07
F2	6.35	P2	2.28	P2	7.93
P3	6.00	F2	2.00	P1	7.71
P1	5.72	F4	1.75	P4	7.16
P4	5.03	F1	1.64	F2	6.96

[1]Numbers connected by the same bracket do not differ significantly at the 5-percent level of probability.

[2]Numbers are not additive because a few observations were graded at each location that were not graded at both.

Discussion and Recommendations

Generally, there was a greater range of damage among eggs in foam cartons than among those in pulp cartons, although damage rate differences between the two groups were minimal.

There was significant difference in total egg damage rates between material groups only when the effect of master containers was considered. However, the pattern of damage indicated that eggs in the foam carton group had more damage at the plant, and eggs in the pulp carton group had more at destination.

Differences in eggshell damage rates between material groups were quite apparent when cartons were packed in 15-dozen baskets (table 11) as opposed to 30-dozen cases (table 7). When cartons were packed in 15-dozen baskets, eggs in the foam carton group had significantly more total damage, most of which occurred at the packing plant, than eggs in the pulp carton group. When cartons were packed in 30-dozen cases, however, there was no significant difference in total eggshell damage rates between foam and pulp cartons.

There was only one repetitive function at the plant up to the point of inspection that might account for the above difference in damage rates between carton materials in baskets. This was the function of manually packing cartons into baskets at the end of the packing line. It therefore appears not only that eggs in the foam carton group received more damage than eggs in the pulp carton group at the plant when 15-dozen baskets were used, but that this damage seemed to occur during the process of packing the cartons into the baskets. Further research in this area is recommended.

Throughout this study, cartons F1, F2, P1, and P2 consistently performed at or above average, and did not differ significantly from each other. However, this does not preclude other cartons tested since most performed adequately. Because of the range of eggshell damage within the material groups, it is recommended that choice of cartons be made on their individual merits based on type of master container being used as reflected in this research.

This report should not be the sole determining factor in choice of cartons or master containers. Marketing strategies and handling systems costs need to be examined and the optimum mix obtained.

Appendix—Sampling Procedures

At each checkpoint, graders inspected (candled) 100 shell eggs from each sample 30-dozen fiberboard case or 15-dozen basket. One-half of the total eggs candled from the fiberboard cases were taken from the numbered end of the cases and the other one-half from the opposite end of the cases. For example, on odd-number cases, such as 1, 3, and 5, the marked end of the case was examined, and on the even-number cases, such as 2, 4, and 6, the unmarked end was examined.

Eggs within each case and basket were selected in the following rotation:

Container 1 - Cartons in layers 1, 2, and all except eight eggs in the third layer.

Container 2 - Cartons in layers 3, 4, and all except eight eggs in the fifth layer.

Container 3 - Cartons in layers 2, 3, and all except eight eggs in the fourth layer.

Container 4 - Cartons in layers 1, 2, and all except eight eggs in the fifth layer.

Container 5 - Cartons in layers 1, 4, and all except eight eggs in the fifth layer.

The above order of selection was repeated for all remaining sample fiberboard cases and baskets.

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